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Indices for Working Land Conservation: Form Affects Function

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Using environmental indices (EIs) to rank applications for enrollment in conservation programs is becoming common practice. However, there is little guidance on how it should be done. The indices adopted by existing programs have often been linear, using weighted averages of environmental parameters without explicit consideration of whether they represent a reliable preference ordering on environmental states. Our article investigates society's weights for addressing multiple resource concerns and how functional forms of EIs can influence program outcomes. We propose a means by which preference weights are observed from policymaker actions. Weights for multiple resource concerns are determined and combined with biophysical crop simulation data to create an environmental index (EI) for crop rotations. This index is developed using alternative function forms to score conservation efforts on working cropland and to measure their effect on program outcomes.

The United States is a major producer of many crops, including corn, soybeans, and sorghum. Approximately 340 million acres of cropland were cultivated in 2002, resulting in an estimated $100 billion of farm revenue (U.S. Department of Agriculture; Economic Research Service). However, there are several byproducts of producing crops, including soil erosion and chemical runoff and leaching. The U.S. Department of Agriculture (USDA) funds various conservation programs to reduce these adverse effects. Indeed, over the next six years, Congress has authorized upwards of $10 billion on conservation measures—approximately half for the Conservation Reserve Program (CRP) and half for working lands programs, such as the Environmental Quality Incentive Program (EQIP).

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The number of potential participants for these programs is large and the environmental goods and services sought after have many dimensions. Acknowledging this, program managers increasingly use EIs to rank farmer applications for conservation program enrollment. The advantage of using indices is that they summarize large quantities of information using a systematic procedure to weight, scale, and aggregate multiple variables into a single measure. Once this procedure has been defined, program managers and farmers can compare alternative applications and evaluate program outcomes across regions and/or over time.

Combining EIs with conservation programs has gained momentum since the development of the Environmental Benefits Index (EBI) in the mid 1990s (USDA, Farm Service Agency). The EBI is used to rank CRP applications and compare program outcomes (Babcock et al.). However, compared to land retirement programs, working land conservation programs provide smaller and more varied incentive payments per acre for a much wider range of production practices. Program managers also use EIs to rank EQIP applications (USDA, Natural Resources Conservation Service; Searchinger, Friedman, and Heimlich); however, there is no standardized approach for evaluating program outcomes across states, making it difficult to assess the effectiveness of this program over time or space.

A standardized environmental index (EI) approach to ranking contracts for working land programs, such as EQIP, and for measuring their outcomes would hypothetically weight the environmental parameters that affect the relevant resource concerns addressed under the program and compute a score for each producer's application, based on the suite of best management practices proposed and relevant land characteristics. Program managers could use these scores to screen for cost-effective applications for enrollment. An EI score could also provide a basis for distributing program payments—higher scores would result in larger payments—explicitly rewarding cost-effectiveness (see, e.g., Cattaneo et al.).

However, there is little guidance on how to construct a standardized EI that allows for multiple practices or how to develop the preference weights needed to address multiple resource concerns in different regions (Heimlich; Searchinger, Friedman, and Heimlich; Ferraro). For example, is it relatively more important to increase carbon sequestered on an acre of cropland in the Northern Plains or to reduce the nitrogen leached into the groundwater supplies; and is it relatively more important to reduce sheet and rill erosion or wind erosion in the Corn Belt? Even with preference weights for a heterogeneous set of environmental parameters, there is less guidance on how to use them to construct a representative EI for ranking program applications.

A number of descriptive EIs have been proposed in recent years, ranging from measures of overall environmental quality (van den Bergh and van Veen-Groot) to more targeted measures of air and water quality (Khanna). However, there is a lack of external criteria to evaluate the effectiveness of such measures. This is an important gap because difficulties may arise in comparing environmental states given the variety of measurement units in which environmental parameters can be expressed (mass, concentration, number of species, tons per acre for soil erosion, etc). Those indices adopted by existing programs have often been linear, using weighted averages of environmental parameters developed by experienced practitioners, but without explicit consideration of whether they represent a reliable preference ordering on environmental states (Ebert and Welsch).

Our article addresses these concerns in the context of the U.S. agri-environmental programs for working cropland; that is, what are society's preferences for addressing multiple resource concerns and how can functional forms of EIs influence program outcomes? This article proposes a means by which preference weights are inferred from policymaker actions. These weights are combined with environmental parameters to create standardized EIs for cropping enterprises based on alternative functional forms. We then use an economic and environmental simulation model to assess the performance of these indices at the regional and national levels. We discuss the simulation results in the context of increasing levels of federal assistance for conservation efforts on the U.S. cropland.

EIs for Working Lands

Developing an EI that aggregates multiple-dimensional information into a single summary output requires: (i) the choice of resource concerns to be addressed under the conservation program; (ii) assignment of unit scale for each parameter; (iii) weights signaling trade-offs between environmental parameters that affect the resource concerns; and (iv) the functional form used to aggregate the parameters into a single summary output for evaluation purposes. The environmental parameter units, whether they are normalized, and the functional form of the index will determine whether the index is an appropriate representation of a preference ordering on environmental states; that is, whether the ordering represented by the index is unambiguous and invariant to the choice of units used to measure subcomponents. In the following sections, we address these steps and analyze the implications for working lands programs of the choices underlying the use of an index to rank applications.

Scaling and Environmental Parameters

U.S. agricultural production affects many resources. This analysis examines a range of nine environmental parameters affecting four resource concerns: surface water (sheet and rill erosion, nitrogen, phosphorus, and pesticides), ground water (nitrogen and pesticides), air (wind erosion and carbon emissions), and soil (decreasing productivity). We compute an EI score (EI_{ki}) for each cropland acre employing cropping system (i) in region (k). This score is composed of a "relative discharge estimate" (RDE_{kji}) for each of the environmental parameters (subscript j), which is a measure of the quantity of the parameter leaving the field and arriving at the relevant media (the exception being losses of soil productivity, which are measured in dollars).

Cropping systems having relatively low RDEs indicate generally cleaner production practices; conversely, those with high RDEs are contributing higher quantities of pollutants to the environment. To characterize a cropland acre using the ith crop production system and its potential to generate environmental benefits in the kth region, relative discharge estimates are normalized to a 0–1 impact index (I_{kji}) for each parameter

$$I_{kji} = \left(\frac{\mathrm{RDE}_{kji} - \min(\mathrm{RDE}_j)}{\max(\mathrm{RDE}_j) - \min(\mathrm{RDE}_j)}\right),$$

where $\min(\mathrm{RDE}_j)$ and $\max(\mathrm{RDE}_j)$ are the minimum and maximum discharge estimates across all systems and regions for the jth environmental parameter. Such normalization is common to address incommensurability between different subcomponents that are measured using different units (Roberts; Hammond). Otherwise, the effective weight of a subcomponent could depend on the unit of measure (e.g., pounds of nitrogen discharge versus value of soil productivity).

Functional Forms

The environmental parameters chosen for our EIs are not highly correlated at the national level (table 1). While there are exceptions (i.e., practices that reduce sheet and rill erosion also tend to lower phosphorus discharge at similar rates), some practices that address one resource concern may actually impair another (in the case of negative correlations). Therefore, the impact indices are combined to generate an EI score specific to each production system, reflective of the total management effects of that system on the environment.[1]

We first examine a weighted sum of the environmental parameters (*Additive*), where w_{kj} are preference weights for addressing a particular resource concern via reducing the given environmental parameter

$$EI_{ki} = \sum_j w_{kj} I_{kji}.$$

This functional form assumes impacts on the environment are aggregated linearly in the environmental parameters and is currently used in the EBI (USDA, Farm Service Agency) and in local indices used to rank EQIP contracts (USDA, Natural Resources Conservation Service). This form has intuitive appeal, but assumes a preference ordering whereby environmental variables are perfect substitutes.

Ebert and Welsch analyzed the impact of measurability and comparability on the existence conditions and functional forms necessary for EIs to be unambiguous orderings given the normalization adopted. They found that indices in the form of an arithmetic mean (such as *Additive*) are generally ambiguous because the required property of interval scale unit comparability is not satisfied by the parameters employed. Here, our impact indices (I_{kji}) are ratio scale measurable variables. They have a natural origin (i.e., the least impact that can be attained, or $\min(\mathrm{RDE}_j)$), but their scaling can be changed independently (i.e., they are ratio scale noncomparable). Ebert and Welsch show that a weighted geometric mean (multiplicative form) aggregation can generate an unambiguous index in situations where ratio scale comparability is violated. Therefore, a weighted product of the individual environmental parameters is next examined (*Geometric*):

$$EI_{ki} = \prod_j I_{kji} \wedge w_{kj},$$

Table 1. Correlation between impact indices at the national level

Impact Indices	Sheet and Rill Erosion	Nitrogen Discharge	Nitrogen Leaching	Phosphorus Discharge	Soil Productivity Loss	Wind Erosion	Carbon Emissions	Pesticide Discharge	Pesticide Leaching
Sheet and rill erosion	1.00								
Nitrogen discharge	0.58	1.00							
Nitrogen leaching	0.01	0.14	1.00						
Phosphorus discharge	0.63	0.85	0.20	1.00					
Soil productivity loss	0.05	0.03	−0.09	0.11	1.00				
Wind erosion	−0.11	−0.18	−0.17	−0.16	0.00	1.00			
Carbon emissions	0.20	0.20	−0.01	0.17	−0.13	0.12	1.00		
Pesticide discharge	0.24	0.20	−0.01	0.28	−0.03	0.00	0.09	1.00	
Pesticide leaching	−0.02	0.02	0.31	0.06	−0.02	−0.08	−0.14	0.03	1.00

where w_{kj} are similar preference weights on addressing alternative resource concerns via reductions in the environmental parameters.[2] The purpose of comparing the two types of indices is that they represent the same preference judgments (i.e., w_{kj}'s), but may result in very different program outcomes.

Indicator Weights

There are a number of ways to derive estimates of society's preferences about reducing pollution (King and Mazzotta). One means is to ask people how they would value a change in the amount of a pollutant that is released into the environment. In theory, higher levels of reduction are associated with increasing environmental benefits and correspondingly greater values (e.g., fertilizer runoff into lakes—Stumborg, Baerenklau, and Bishop). Others have used travel cost methods to determine how valuable variable recreation opportunities are to the public (e.g., sediment loads and fishing recreation—Feather, Hellerstein, and Hansen) or hedonic analysis to reveal how preferences of consumers are affected by variable environmental quality (e.g., sulfur and nitrogen and housing prices—Kim, Phipps, and Anselin). These studies highlight the fact that previous research of valuing environmental impacts typically focused on a single resource concern or environmental parameter in a single region.

For the case of multiple pollutants across regions, a different approach is required. We examine conservation program expenditures to "reveal" how society values efforts to improve different resource concerns across regions. Some contend that federal expenditures reveal successful rent seeking by an organized few (Runge, Schnittker, and Penny), yet there is also evidence that public preferences may translate into policymaker expenditures and mandates (Variyam and Jordan; Besley and Burgess; Dixit, Grossman, and Helpman; Crémer and Palfrey). Looking more closely at conservation programs, (Bastos and Lichtenberg) showed how incentive payments are linked to public preferences for environmental quality. And, while the link between policy expenditures for working land programs, environmental standards, and public preferences may not be completely transparent, Reichelderfer and Boggess noted that policymakers can learn and improve the cost-effectiveness of conservation program controls.

Our sources of data are regional EQIP expenditures on cropping conservation practices (we exclude livestock-related practices) between 1997 and 2002 (USDA, Economic Research Service). EQIP contracts are distinguished by region and by the primary environmental parameter affected (nutrient runoff, pesticide runoff, pesticide leaching, nitrogen leaching, wind erosion, sheet and rill erosion, and soil productivity). EQIP expenditures are not based on actual physical measures, but rather on how various management practices are expected to address different resource concerns, and so are well suited to the normalization procedure used to develop I_{kj}'s in our EI. Regional weights are developed by aggregating EQIP contract amounts in each region by environmental parameter (table 2). For example, because EQIP does not address greenhouse gas emissions, carbon sequestration receives a weight of zero in the index. In addition, because we separate data at the regional level and only compare relative expenditures by environmental parameter, we limit the exposure of our weights to bias introduced through possible rent seeking.

Table 2. Regional preference weights

	Regions[a]									
Environmental Parameter	**AP**	**CB**	**DL**	**LS**	**MT**	**NP**	**NT**	**PS**	**SP**	**ST**
Carbon emissions	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wind erosion	0.01	0.00	0.00	0.02	0.10	0.18	0.03	0.08	0.02	0.00
Soil productivity loss	0.43	0.48	0.62	0.52	0.61	0.51	0.22	0.35	0.46	0.41
Pesticide leaching	0.07	0.05	0.07	0.06	0.01	0.01	0.06	0.08	0.00	0.02
Nitrogen leaching	0.13	0.10	0.05	0.13	0.13	0.07	0.20	0.07	0.03	0.16
Pesticide discharge	0.00	0.02	0.00	0.02	0.00	0.03	0.06	0.11	0.04	0.02
Sheet and rill erosion	0.31	0.16	0.22	0.10	0.14	0.10	0.13	0.10	0.27	0.05
Nitrogen discharge[b]	0.03	0.10	0.01	0.08	0.00	0.04	0.17	0.11	0.10	0.23
Phosphorus discharge[c]	0.02	0.09	0.02	0.08	0.00	0.05	0.14	0.09	0.07	0.10

[a]Regions: Northeast (NT) = CT, DE, MA, MD, ME, NH, NJ, NY, PN, RI, VT; Lake States (LS) = MI, MN, WI; Corn Belt (CB) = IA, IL, IN, MO, OH; Northern Plains (NP) = KS, ND, NE, SD; Appalachia (AP) = KY, NC, TN, VA, WV; Southeast (SE) = AL, FL, GA, SC; Delta States (DS) = AR, LA, MS; Southern Plains (SP) = OK, TX; Mountain (MT) = AZ, CO, ID, MT, NM, NV, UT, WY; Pacific States (PS) = CA, OR, WA.

[b,c]The Environmental Quality Incentives Program data do not distinguish between the types of nutrients addressed by management practices for surface-water quality. The discharge of either nitrogen or phosphorus can result in water impairments (Scasso et al.). Therefore, we use the Environmental Protection Agency (EPA) nutrient criteria for rivers, streams, lakes, and reservoirs (EPA, 2004) to develop preference weights for reducing nitrogen and phosphorus runoff. The ratio of nitrogen to phosphorus reduction to meet these criteria gives an indication of the relative importance of reducing the two nutrients. Given the nitrogen and phosphorus RDEs, weights are developed for each region and are then multiplied by the EQIP-derived preference weight for reducing nutrients to surface water (see Cattaneo et al. for more details).

Form and Function

Economic and Environmental Model

Using the two different functional forms discussed above, a policy rewarding improved environmental performance is simulated using the U.S. Regional Agricultural Sector Mathematical Programming Model, a comparative static, spatial and market equilibrium model that incorporates agricultural commodity, supply, demand, environmental impacts, and policy measures (House et al.). This model has recently been applied to examine climate change mitigation (Peters et al.), water quality policy (Ribaudo, Heimlich, and Peters), and conservation policy (Cattaneo et al.). The model includes forty-five geographic subregions, which are further distinguished by erosion potential. Twenty-three inputs are included, along with production and consumption of forty-four agricultural commodities and processed products.[3]

Regionally specific extensive (animal and crop production levels) and intensive (crop rotations, tillage, and fertilizer practices) management practices are endogenously determined. Substitution among the cropping activities is achieved using nested constant elasticity of transformation functions. The transformation elasticities are consistent with domestic supply response in the USDA's Food and Agriculture Policy Simulator (Westcott, Young, and Price) and with trade responses in the USDA Economic Research Service/Penn State Model (Stout and

Abler). Nonlinear supply response functions reflect declining marginal rates of transformation between crop rotations and tillage activities, which allows smooth adjustments to changes in relative returns across production enterprises.

The Environmental Policy Integrated Climate Model (Mitchell et al.), a multi-year, daily simulation of weather, hydrology, soil temperature, erosion sedimentation, nutrient cycling, tillage, crop management and growth, and pesticide movements, predicts how cropping, tillage, and fertilizer choices result in edge-of-field environmental parameters. The transport of nutrients, pesticides, and sediment across the landscape is calibrated to the U.S. Geological Survey estimates of regional pollutant loads (Smith, Schwartz, and Alexander). With the exception of soil productivity (measured in reduced long-run revenue due to reduced yields—House et al.) and pesticides leaching and runoff (measured in toxicity persistence units—Barnard et al.), the resulting relative discharge estimates measure the pollutant mass reaching the relevant environmental medium. Summing across cropland acres yields estimates of total discharge or emission of environmental externalities into the environmental annually (see "Base" levels in table 3).

Policy Simulations

Our regional agricultural sector model is first calibrated to regularly updated production practices surveys using a positive math programming approach (Howitt), the USDA multi-year baseline (USDA, World Agricultural Outlook Board), and the National Resources Inventory (USDA, Natural Resources Conservation Service), solving for optimal production levels for cropping enterprises (X_{ki}) and livestock activities (X_{kl})

$$\max_{X_{ki}, X_{kl}} \sum_{ki} (P_i - VC_{ki}) X_{ki} + \sum_{kl} (P_l - VC_{kl}) X_{kl}.$$

Here P_i and P_l are equilibrium prices for cropping and livestock activities; VC_{ki} and VC_{li} are regional variable costs of production. Both cropping and livestock choices are modeled due to their interaction via the feed sector. Next, conservation payments are simulated for reducing the number of EI points generated from crop production

$$\max_{X_{ki}, X_{kl}} \sum_{ki} (P_i - VC_{ki}) X_{ki} + PPT \sum_{ki} \left(X_{ki}^0 - X_{ki}\right) EI_{ki} + \sum_{kl} (P_l - VC_{kl}) X_{kl},$$

$$\text{subject to } B \geq PPT \sum_{ki} \left(X_{ki}^0 - X_{ki}\right) EI_{ki} \text{ and } \sum_i X_{ki}^0 = \sum_i X_{ki} \forall k.$$

The analysis assumes that an exogenously determined budget (B) constrains total payments for environmental improvements. A fixed agri-environmental price per EI point (PPT) is offered under the conservation program to improve environmental performance on croplands. The price per point is chosen exogenously so that optimal choice of X_k given PPT just meets the budget constraint. Two budget levels are simulated: $1 billion and $500 million. In addition, an acreage constraint

Table 3. Effect of functional form of index on environmental performance: national aggregate

Environmental Parameters	Base[a]	$1 Billion Program		$500 Million Program	
		Additive	Multiplicative	Additive	Multiplicative
Sheet and rill erosion (tons)	204	21.18	12.98	15.69	8.42
Nitrogen leaching (lbs)	1,687	16.94	11.27	11.19	9.58
Nitrogen discharge (lbs)	3,450	15.28	15.25	11.49	7.70
Phosphorus discharge (lbs)	222	18.39	13.36	14.40	9.00
Soil productivity loss ($'s)[b]	305	256.95	80.59	203.18	67.36
Wind erosion (tons)	269	15.29	18.77	10.36	12.33
Carbon emissions (tones)[c]	111	8.31	10.80	5.37	7.06
Pesticide discharge (TPUs)[d]	527,031	11.56	8.24	5.70	3.94
Pesticide leaching (TPUs)	36,444	14.98	15.73	11.33	11.40

[a]Baselines are calibrated for projected cropping patterns in 2010 (USDA, World Agricultural Outlook Board).Units are measured in millions and do not include discharge from animal production.

[b]Soil productivity losses are the net present value of short-run revenue minus long-run revenue (House et al.).

[c]Carbon emissions are calculated according to the Intergovernmental Panel on Climate Change estimates (IPCC). The values indicate the amount of carbon emitted when converting land from native pasture.

[d]TPUs refer to "toxicity persistence units" (Barnard et al.). These refer to the sum of reference doses (maximum daily human exposure resulting in no appreciable risk) of the pesticides used for a particular cropping enterprise multiplied by the number of days, each of those pesticides remains active in the environment. As a point of reference the number of TPUs in a pound of DDT = 4,443 million and in a pound of Borax = 103,872.

is imposed, where $\sum_i X_{ki}^0$ is the amount of cropland acres in region k before implementing the conservation program and $\sum_i X_{ki}$ is the amount of cropland acres in region k after implementing the program. In other words, producers cannot receive program payments for environmental benefits generated from retiring land from production or for land that had not previously been cropped.

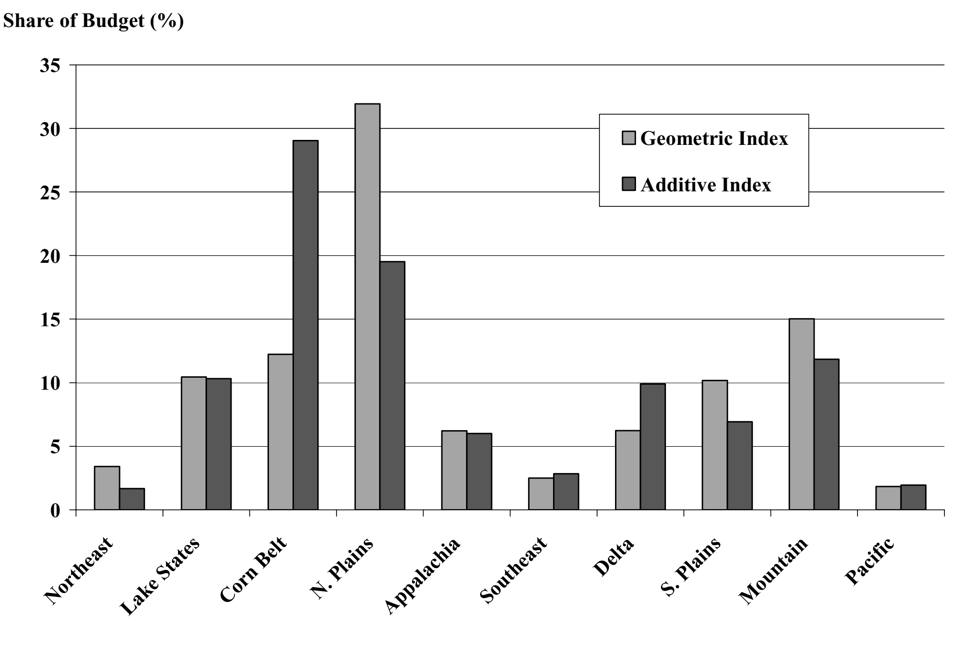
Simulation Results

Same Preference Weighting, Different Geographic Distribution of Program Funds

In our policy simulation, funds flow according to performance-based criteria; that is, funds are directed toward geographic areas providing the greatest benefits according to the scoring mechanism being considered. Funds allocated to a region will also depend on the number of acres to be treated and at what cost. Therefore, the amount of cropland acres in a region is likely correlated to the amount of funds received for conservation. This is indeed the case, as the results indicate the two largest regions, the Northern Plains (70.2 million acres) and the Corn Belt (97.5 million acres), attract a large share of the available funds. However, the difference between using an additive index versus a geometric one is substantial (figure 1). For example, the Corn Belt would receive nearly 30% of funds under an additive screening, as opposed to 12% with a geometric index. The Northern Plains, instead, are favored by the adoption of a geometric index (32% of funds) versus an additive one (20% of funds).

The dualism between the two regions that would be receiving the greatest funding under the additive and geometric indices, the Corn Belt and the Northern

Figure 1. Share of funds to region by index type (1 billion $US budget)



Plains, respectively, can be explained in terms of the balance between the different objectives provided by the two regions. Because the Corn Belt provides a much greater potential to improve soil productivity (which has the largest weight) than the Northern Plains and since using an additive index is equivalent to considering the benefits from different objectives as perfect substitutes, a program screening with an additive index will direct funds more toward the Corn Belt. Alternatively, the Northern Plains potentially provides more balanced environmental outcomes across objectives than the Corn Belt, therefore leading to higher geometric index scores and more funds going to the Northern Plains.

The implication of the results presented above are that the same set of weights can lead to radically different distribution of funds for conservation across geographic areas, depending on the functional form used in screening applications. The fact that additive indices have been the standard choice (e.g., for CRP and EQIP), does not necessarily make them any more appropriate to the task of screening than a geometric index. The large difference in how conservation funds for working lands would be distributed indicates that it may be worthwhile considering a geometric index, especially in the light of recent results that these indices may better reflect the trade-offs between objectives.

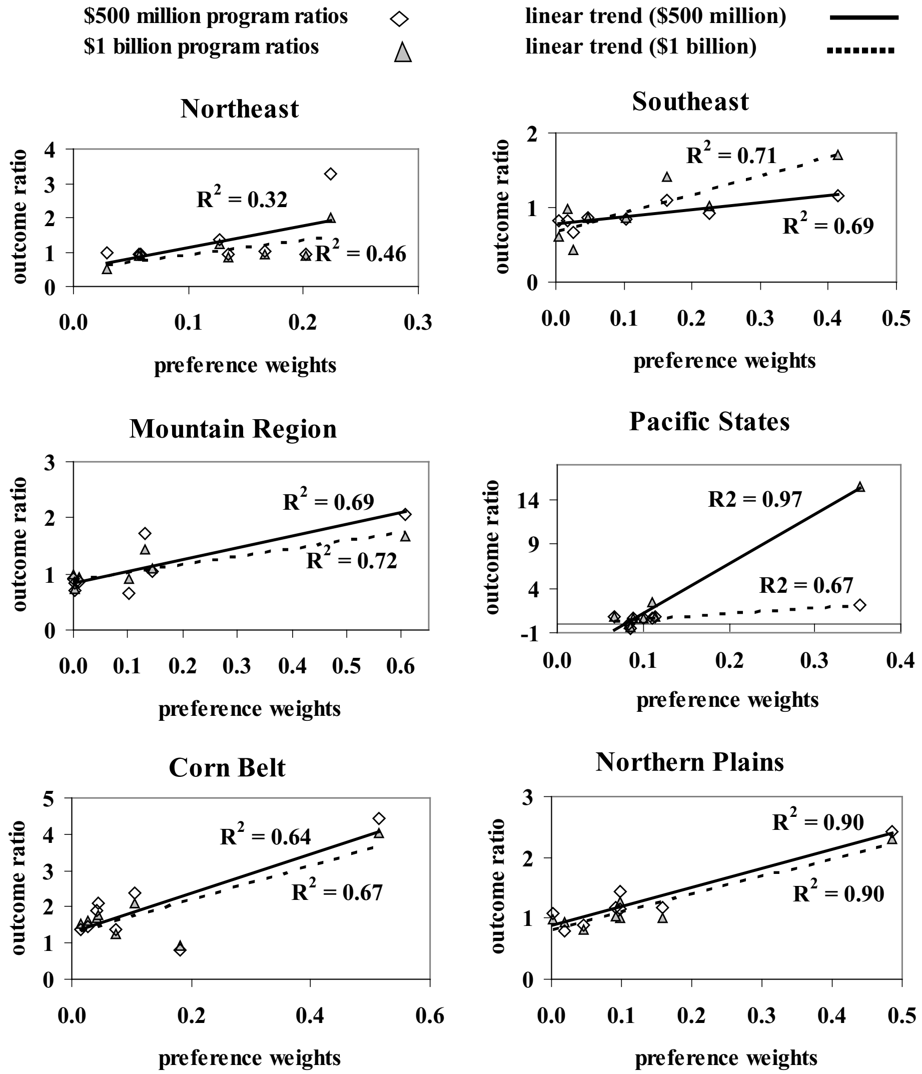
Same Preference Weighting, Different Potential Environmental Impacts

The environmental outcomes of the simulation exercise are meant to reflect, for the most part, the weighting scheme chosen. However, the functional form used to construct the screening index, combined with the possibility of practices that address one resource concern impacting others, may result in different outcomes even for a given set of weights. The additive index will tend to put greater emphasis than the geometric one on improving the objective with the greatest weight. The geometric index considers benefits from environmental objectives as imperfect substitutes. This tendency can be either emphasized or attenuated by the degree of complementarity or substitutability in providing these benefits through conservation measures.

For example, even though these preference weights do not directly reward practices that suppress carbon emissions, other practices that are rewarded (e.g., those that increase soil productivity or reduce sheet and rill erosion) may be associated with carbon sequestration. Hence, it is difficult to say *ex ante* how the potential environmental outcome of a conservation program might change if one uses an additive or a geometric index. The issue is essentially an empirical one, that of determining the order of magnitude of the differences. From the geographic distribution of funds, it would appear that changing the functional form may have a dramatic impact on the program outcome.

The results aggregated at the national level (table 3) highlight how soil productivity, which is consistently weighted the most in all regions, improves more when screening is accomplished using an additive index. Across the environmental parameters examined, improvements range from 3% for carbon sequestration to more than 200% for soil productivity. The high percentage increases for soil productivity reflect that management changes under these conservation programs result in soil productivity gains (i.e., yields are increasing over time) versus baseline soil productivity losses under current practices.

Figure 2. Environmental outcome ratios and preference weights*



* Outcome ratio by objective (y-axis) = additive screening environmental outcome ÷ geometric screening environmental outcome.

This general trend is reflected to a larger extent at the regional level. It is difficult to present disaggregated results for ten Farm Production regions, so we present a representative subset of the regional results to provide some insight into how different regions would address conservation concerns. We also consider how the index used to screen application can make a big difference in potential environmental outcomes. Results are provided for six out of ten regions used in the simulations (Northeast, Southeast, Mountain, Pacific States, Corn Belt, and Northern Plains).

In figure 2, on the y-axis we plot the ratio of the outcome obtained with the additive index over the outcome obtained with the geometric index. These are presented as a function of the weights assigned to objectives in a region (x-axis). Each point describes the weight assigned to the objective and whether the associated objective did better using the additive index (outcome ratio > 1) or the geometric index (outcome ratio < 1). Results are plotted for $500 million and $1 billion funding levels, and a simple linear regression is shown for each set of points.

It is immediately apparent that soil productivity, which has the highest weight in every region, performs much better when an additive index is used (i.e., outcome ratios > 1), as was seen in the national-level results. From the regressions, we see that the weights are good predictors of discrepancies between environmental outcomes for additive versus geometric screening.

The Northeast region has the most balanced weighting scheme, and therefore one would expect to have smaller discrepancies between the two indexing approaches. This is true for most objectives considered, where we find a ratio of approximately 1.0, except for soil productivity, which still is the highest-weighted objective (the data for all the graphs are reported in table 4). Soil productivity improves twice and thrice as much with the additive index than the geometric index, with the $500 million and $1 billion programs, respectively. It is surprising that this increased performance does not come to great detriment of the other objectives for the smaller budget case (other objectives' performance ratios are only marginally below 1). This phenomenon may be due to complementarities between objectives (recall table 1) that can be exploited as the program is relatively small, but that become exhausted at higher budget levels.

Apart from the Northeast, all the other regions have more pronounced imbalances in the weights. The uneven weight distribution indicates that the outcomes obtained using the additive index are skewed in favor of the heavily weighted soil productivity objective. For example, the extra improvement (of an additive screening versus geometric one) for soil productivity obtained in the Pacific States region, comes at the expense of the majority of the other objectives, which are clustered below the ratio value of 1.0. Indeed, pesticide leaching actually increases in this region under the geometric index, resulting in a negative outcome ratio. A similar trade-off would occur to a lesser degree in the Southeast and the Mountain regions. In all these regional cases, when using an additive index, the ratio of the percentage improvements in soil productivity relative to those of other objectives, exceed by far the relative importance assigned to soil productivity. The geometric index attenuates this imbalance.

We also note that the budget level can have an impact on the interaction between weights and environmental outcomes (as is the case for the Pacific States region). With a higher budget, more environmental improvements will be realized, but at a decreasing rate, as the options for further environmental improvements become more limited. The fact that a $1 billion conservation program purchases about 1.5 times the amount of environmental improvements as a $500 million conservation program supports this point (recall table 3). Also, a higher budget for a program adopting a linear index (allowing for full substitution between objectives) results in greater emphasis (for the additional funds) being placed on those objectives providing greater benefits. Typically, the objectives chosen as

Table 4. Selected outcome ratios and preference weights

		Environmental Parameters								
Region		Sheet and Rill Erosion	Nitrogen Leaching	Nitrogen Discharge	Phosphorus Discharge	Soil Productivity Loss	Wind Erosion	Carbon Emissions	Pesticide Discharge	Pesticide Leaching
Northeast	Weight	0.13	0.20	0.17	0.14	0.22	0.03	0.00	0.06	0.06
	Ratio ($1 billion)	1.21	0.90	0.92	0.87	1.99	0.50	0.54	0.88	0.90
	Ratio ($500 million)	1.37	0.94	1.01	0.92	3.27	1.00	0.54	0.92	0.93
Southeast	Weight	0.05	0.16	0.23	0.10	0.41	0.00	0.00	0.02	0.02
	Ratio ($1 billion)	0.86	1.42	1.01	0.87	1.70	0.60	0.82	0.99	0.43
	Ratio ($500 million)	0.86	1.10	0.93	0.84	1.16	0.83	0.83	0.82	0.67
Mountain	Weight	0.14	0.13	0.00	0.00	0.61	0.10	0.00	0.00	0.01
	Ratio ($1 billion)	1.11	1.44	0.72	0.72	1.68	0.91	0.78	0.99	0.93
	Ratio ($500 million)	1.04	1.73	0.84	0.71	2.07	0.66	0.83	0.91	0.87
Pacific	Weight	0.10	0.07	0.11	0.09	0.35	0.08	0.00	0.11	0.08
	Ratio ($1 billion)	0.67	0.89	2.49	0.72	15.53	0.00	0.64	0.75	−0.39
	Ratio ($500 million)	0.68	0.78	0.72	0.70	2.19	0.00	0.62	0.79	−0.51
Corn Belt	Weight	0.10	0.07	0.04	0.05	0.51	0.18	0.00	0.03	0.01
	Ratio ($1 billion)	2.10	1.25	1.69	1.78	4.03	0.91	1.09	1.60	1.53
	Ratio ($500 million)	2.39	1.39	1.91	2.08	4.43	0.82	1.07	1.44	1.38
N. Plains	Weight	0.16	0.10	0.10	0.09	0.48	0.00	0.00	0.02	0.05
	Ratio ($1 billion)	1.00	1.27	1.01	1.04	2.31	0.97	0.72	0.93	0.82
	Ratio ($500 million)	1.16	1.44	1.14	1.18	2.43	1.07	0.72	0.80	0.89

providing better benefits will be those more heavily weighted unless the program size drives up their marginal cost beyond the marginal benefit implied by their weight. We find that the impact of the functional form by budget size differs at the regional level.

The Corn Belt and the Northern Plains are the two largest would-be recipients of working lands funds and these show a strong relationship between the weight assigned to an objective and the ratio of its outcome in the program using an additive screening versus a geometric one. Interestingly, the emphasis on soil productivity does not deter the attainment of many other objectives if an additive index is used. For the Corn Belt region, this is explained by the use of an additive index, which brings more conservation funds to this region (as was shown in figure 1). These additional funds allow nearly all objectives to perform better when using the additive index.

More difficult to explain is the outcome for the Northern Plains where, even though the additive index attracts fewer funds, the environmental outcome for many objectives is better using the additive index than the geometric one (albeit most outcome ratios are near 1.0). A plausible explanation, which would need further investigation, is that complementarities between soil productivity and the other objectives in the Northern Plains can compensate for the lower funds and for the tendency of the additive index to view different objectives as perfect substitutes. Another explanation for future study is that the majority of the environmental goods and services available through working lands conservation (e.g., in the Northern Plains) may be purchased at a relative discount. This implies that the decreasing rate of environmental return for higher budgets occurs at a greater rate in the Northern Plains *vis-à-vis* other regions.

Summary

Like the CRP, new conservation initiatives for working agricultural land will likely undergo a number of program iterations as policymakers seek to enhance program cost-effectiveness and as public concern over resource impairments change. To facilitate these iterations, we present a method to compare individual contracts and overall program outcomes when multiple resource concerns are addressed. We use relative public preferences to aggregate across nine environmental parameters. These preferences are distilled from national criteria for water quality standards and from past EQIP data.

Providing a set of preference weights that reflect the relative importance of addressing different environmental parameters that affect resource concerns in different regions is the first of two contributions of this article. We find that the weights vary substantially across regions, indicating that a national index like the EBI may misrepresent regional priorities of working lands programs, which support a wider set of production practices and address multiple resource concerns.

The second contribution of the article is to illustrate, using empirical simulations, how the form chosen for an EI can significantly affect program outcomes. Each management practice on working cropland affects multiple resource concerns, so it is difficult to predict *ex ante* what the impact of the two different approaches will be for environmental performance. The results of the simulations indicate that screening applications with an additive index puts a much greater emphasis on addressing the most heavily weighted objectives, often leading to a disconnect between the relative magnitude of the objective weights, and the environmental outcomes. We also find that the interaction between weights and the functional form of the index can depend on the budget provided for the program. We find that enhancements in environmental performance on working cropland come at an increasing cost regardless of the functional form chosen.

Given that the use of environmental screening of applications in conservation programs is expanding, our results shed light on two critical issues central to this process: (i) how to determine preference weights for addressing multiple resource concerns, and (ii) how sensitive program outcomes are to the choice of functional form for aggregating environmental parameters used to rank program applications. The former issue is well known in the literature, but it is difficult to tackle due to financial resource constraints in eliciting preferences. The approach proposed here is a way to circumvent the difficulties of eliciting preferences from different regions for a menu of environmental parameters that affect resource concerns. The latter issue, choosing an appropriate functional form, does not pose significant empirical challenges (once the weights are estimated), but remains outside the literature concerning conservation programs.

Our analysis investigated geometric indices, which appear to be consistent with social choice theory, as an alternative to the standard additive indices used in CRP and EQIP. The results suggest that the regional distribution of funds and of environmental outcomes of conservation programs that use EIs to distribute funds will depend critically on the functional form used for the screening index. We conclude that it is not enough to estimate the weights to be assigned to environmental objectives; it is also important for a program to provide guidance on how the weights are used to express trade-offs.

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Endnotes

[1] A promising alternative to combining environmental parameters into a single metric via indices is to utilize a distance function approach that minimizes the distance of a suite of environmental parameters enrolled in a program to an optimal environmental quality frontier (Ferraro).

[2] Note that we assume here that environmental preference weights are exogenous to the choice of functional form used to create the index. However, this need not be the case; preferences could change depending on the type of functional form used or conservation program chosen. For example, carbon sequestration is considered under the Conservation Reserve Program, but it is not explicitly considered under the Environmental Quality Incentives Program.

[3] The model accounts for production of the major crop (corn, soybeans, sorghum, oats, barley, wheat, cotton, rice, hay, and silage) and confined livestock (beef, dairy, swine, and poultry) categories comprising approximately 75% of agronomic production and more than 95% of confined livestock production occurring in the United States.

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